BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

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SUBJECT: Position Determination In Lunar Surface EVA - Case 320

DATE: October 22, 1969

FROM: P. Benjamin

ABSTRACT

An attempt is made to relate some of the reasons why an extravehicular crewman on the lunar surface may want to determine his position to the requirements for mechanical aids to permit him to do so. The capabilities suggested are considered in the context of the terrain visited and the accuracy required. Possible methods for meeting the requirements are discussed.

Some reasons why an extravehicular crewman may wish to determine his positions are to traverse to another specified point or to document the position of samples, experiments, or photographs. While the former imposes a real time navigation requirement the latter can be served by post-mission analysis. The navigation system must thus have the capability to guide the astronaut to within visual contact of the objective-the LM or scientific sampling point. Given the prominent landmarks at the prospective J mission sites this requirement may be within the capability of the crewman with minimal or no navigation aids other than a map.

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MEMORANDUM FOR FILE

OBJECTIVES

An extravehicular crewman (EVC) may wish to determine his position relative to some frame of reference for any of four reasons:

1. to return to the LM along the shortest safe route at any time.
2. to traverse to the next sampling site.
3. to document the position of a sample or experiment.
4. to document the origin of photographs.

These four functions, or objectives, form the basis for the definition of navigation requirements for lunar surface traverses. The first objective is a crew safety function. It requires that the EVC have the capability of aborting the mission and returning to the LM in minimum time, consistent with terrain limitations, at any point in the traverse. The other three objectives are mission success functions. The second objective requires the capability to progress from site to site through the traverse. These first two functions require the EVC to be able to determine his position relative to that of some other object. In order to determine path information they also require location of both points relative to a coordinate system - a map. The last two objectives require EVC position information relative to a coordinate system. Combining the objectives, the purpose of navigation is to provide the EVC with the capability to determine the position of some object relative to his current position or to determine the position of the object and his current position relative to a set of coordinates in real time.

It is important to distinguish between navigation and tracking. Navigation refers to the capability for the EVC to determine his position in real time. Tracking applies to the capability for some other party to determine where the EVC is or has been. Given an adequate communications system either navigation or tracking alone might fulfill the functions of both.

ACCURACY

The accuracy required to meet each of the objectives differs. The LM is targeted to land in areas which are relatively flat and have few, if any, obstructions. Thus the LM should be visible at least within a 1 km radius circle about the landing point or would be hidden by one of the few major obstacles which would, in itself, constitute a landmark to aid in locating the LM. To meet the first objective, then, it is necessary at a minimum to locate successfully a 1 km radius circle about the LM. From a radius of 5 km, generally the maximum for J mission traverses, this requires a navigation accuracy of $\pm 20\%$ in distance and $\pm 11°$ in heading.

Sampling sites may be considered as two separate types. To obtain data on lunar morphology, regional material or material on the contacts between stratigraphic units is desired. These samples are obtained in a generalized area rather than at a specific point. Because of the expanse available for regional samples the navigation accuracy requirement to reach these sites is low. Data on specific units, such as the peaks at Copernicus or puncture cones at Marius Hills, requires going to specific points. But these specific points are significant landmarks easily identified in Orbiter photos, and thus probably easily recognizable on the ground. The accuracy required for navigation to such sites probably is of the same order as that required for return to the LM.

The accuracy required to meet the last two objectives is unknown at this time. It does appear that they may impose an after the fact tracking requirement rather than a real time navigation requirement. The functions might be performed, as recently suggested,* by leaving large markers at the origin of samples or photos and photographing the entire landing site later from the CSM. A great deal of position information can also be deduced from panorama photos taken at the sampling site. Thus the primary navigational requirements appear to be operational rather than documentary.

TERRAIN

Landing sites tend to fall into two general categories. On the earlier missions landings are scheduled to be on large,

*D. M. Duty, "LEP Post Traverse Location of Scientific Sites Using CSM Photography," Bellcomm Memorandum for File B69 07047, July 14, 1969.

smooth and relatively featureless areas with relatively bland, amorphous terrain. The geology is homogeneous, and consequently samples chosen near the LM are as representative as those chosen at a distance. Although the bland terrain could easily lead to confusion if the EVC were significantly distant from the LM, there is no requirement for long travereses out of sight of the LM, and thus no navigation requirement.

Increasing confidence in landing capability should permit J missions to land in more rugged terrain with a relatively small, smooth area as the landing target. The wider range of geological formations as evidenced by prominent features requires more extensive traverses, often out of sight of the LM. Sampling within specified areas is also required, and results in navigation requirements as described above. These striking features do, however, provide easily recognizable landmarks (described in Appendix A) which can be utilized as navigation aids. Since the sun is always to the east and shadows are sharp and well defined and point west, it may prove relatively easy to navigate in these sites to the level of accuracy discussed using only the information at hand, and, perhaps, an odometer.

HARDWARE

The simplest navigation system would rely primarily upon the use of landmarks and shadows as aids, requiring only an odometer. If required, the navigation accuracy can be increased a slight amount by formalizing the use of shadows with a sun dial. Both of the above methods require calculation by the EVC (probably mental) to relate heading and position information.

An automatic recording and integrating sun sensor using an odometer input can increase the reliability and accuracy of range and heading information while relieving the EVC of much of the navigation load. This system does not, of course, work in shadows, and is thus forced to average directional data across dark regions. It also incurs a weight and power penalty. A gyro navigation system is independent of the sun and provides even greater accuracy, but at a greater cost in weight and power. The heavier the gyro system the less it drifts and the less it is affected by vibration and jostling.

Thus hardware may be developed at the cost of weight, power, and dollars to increase navigation accuracy and decrease EVC work load. Whether this accuracy is required and whether the costs incurred are commensurate with the work load decrease is open to question.

SUMMARY

There appears to be, at present, no requirement for real time navigation for documentary purposes, and the operational navigation requirement does not appear to necessitate high accuracy. Whereas the featureless terrain of the earlier landings could tend to confuse the EVC if he were relatively far from visual contact with the LM, no requirement for extensive traverses exists. In the later landings longer traverses are required to reach prominent features, but these features themselves provide landmarks for navigation purposes. The use of shadows for compass headings provides additional aid.

There is, therefore, some doubt that any requirement exists which would necessitate the development of navigation hardware. It would seem that additional data on the capability of man to perform this navigation function with minimal mechanical aids would prove useful in making hardware procurement decisions, at least to the level of determining the sophistication required. It is, however, potentially dangerous to proceed on the assumption that no navigation aids are needed and to discover in the middle of a mission that "seat of the pants" navigation is inadequate.

Peter Benjamin

2032-PB-tla P. Benjamin

Attach.

APPENDIX A: NAVIGATION AND LANDMARKS AT THREE J MISSION SITES

MARIUS HILLS

The currently projected landing point is in a valley between four hills which form a rough square, with the valley extending to the four points of the compass. Except for local obstructions the LM should generally be visible from the close side of these hills, and the location of the valley easily distinguished at all times. A distinct puncture cone near the landing site should provide a good reference for return to the LM.

HADLEY-APENNINE

Both the Apennine front and the sinuous rille extend northeast from the projected landing point, bounding a plateau. The shallow depression providing entry to the rille is marked by a crater, and a landing in this area would allow easy location of the LM. Certainly navigation within the rille or near the front should not present major problems.

COPERNICUS PEAKS

The central peaks and the crater wall are very well defined. The closer the LM lands to the peaks the more easily it can be located, and the shorter the traverses need to be. Navigating to the sampling points at the peaks should present no problem, and return to the LM would be complicated only if intervening terrain blocks the LM from view until the EVC is very close to it.

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